P-3 in ARCTAS: Science Goals, Payload and Required Flight Patterns

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<u>Instrument PIs</u>: John Barrick, Anthony Bucholtz, Tony Clarke, Charles Gatebe, Jens Redemann, Sebastian Schmidt, Tony Strawa

Input to Earth Science Project Office & HQ
November 2007

P-3 in ARCTAS

Overall Goal: Contribute measurements and analyses that address the scientific questions posed by ARCTAS's

- Theme 3: Aerosol Radiative Forcing (including indirect aerosol forcing via clouds)

- Theme 2: Boreal Forest Fires

while also contributing to ARCTAS's:

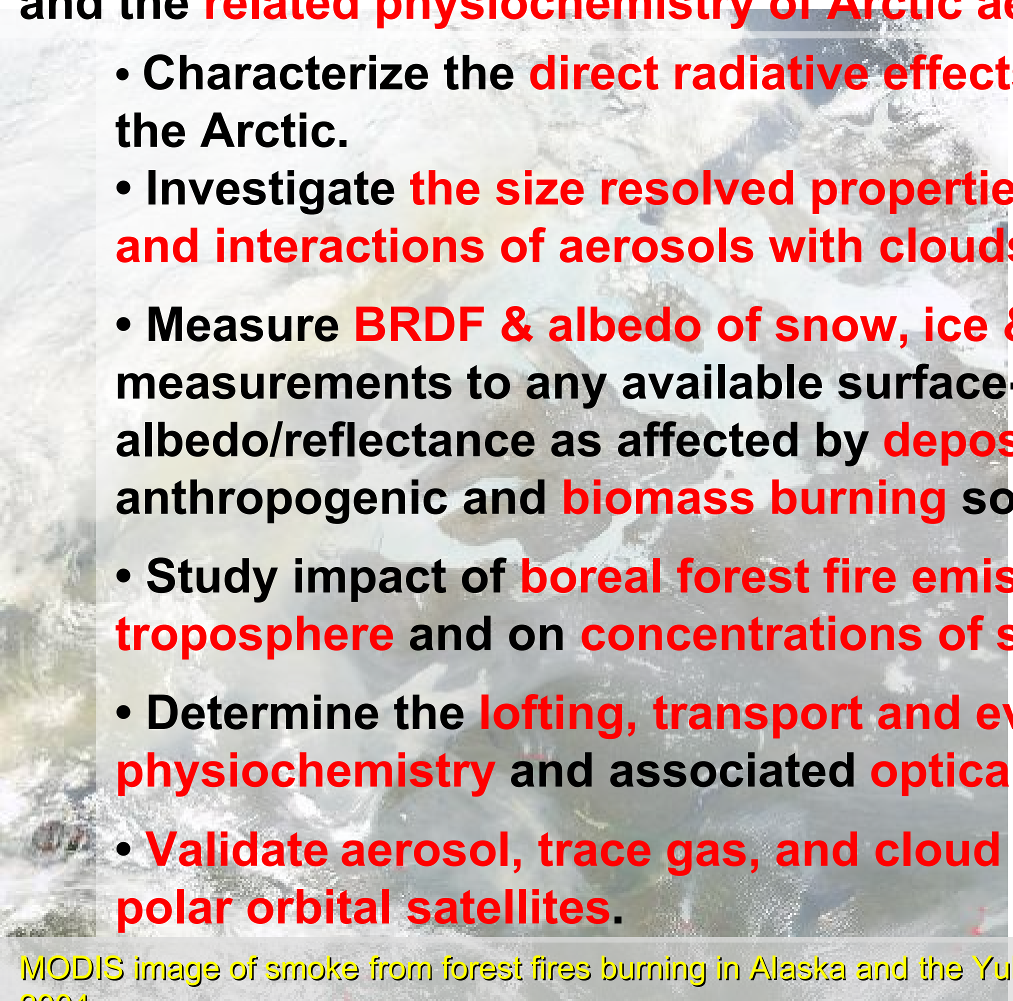
-Theme 1, Long-Range Transport of Pollution to the Arctic,

-Theme 4, Chemical Processes.

With its ARCTAS payload, the P-3 provides a common platform for linking variations in atmospheric radiation to microphysics and chemistry of aerosol as needed for reliable interpretations of satellite inversions and refining model products. This is essential for climate forcing assessment in terms of emissions and or mitigation strategies.

P-3 in ARCTAS

More specifically, we plan to address the following joint POLARCAT-ARCTAS objectives:



- Determine the **vertical layering** of Arctic pollution, **associated optical properties** and the **related physiochemistry of Arctic aerosol**.
  - Characterize the **direct radiative effects** within pollution and smoke layers in the Arctic.
  - Investigate **the size resolved properties of cloud condensation nuclei (CCN) and interactions of aerosols with clouds** and their impact on **radiative forcing**.
  - Measure **BRDF & albedo of snow, ice & other surfaces** and compare those measurements to any available surface-based measurements of snow albedo/reflectance as affected by **deposition of black carbon** from anthropogenic and **biomass burning** sources.
  - Study impact of **boreal forest fire emissions** on the **composition of the troposphere** and on **concentrations of soot, organics and ionic species**.
  - Determine the **lofting, transport and evolution** of smoke aerosol **physiochemistry** and associated **optical properties.**
  - **Validate aerosol, trace gas, and cloud products of space observations from polar orbital satellites**.

MODIS image of smoke from forest fires burning in Alaska and the Yukon, travelling into the Arctic over ice-covered areas, July 2004

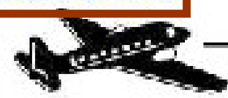
ARCTAS strategy

for enabling exploitation of NASA satellite data to improve understanding of arctic atmospheric composition and climate*

Satellites: CALIPSO, CloudSat, OMI, TES, HIRDLS, MLS, ACE, MODIS, AIRS, MISR, MOPITT

- Aerosol optical depth, properties **
- CO, ozone, BrO, NO_2, HCHO

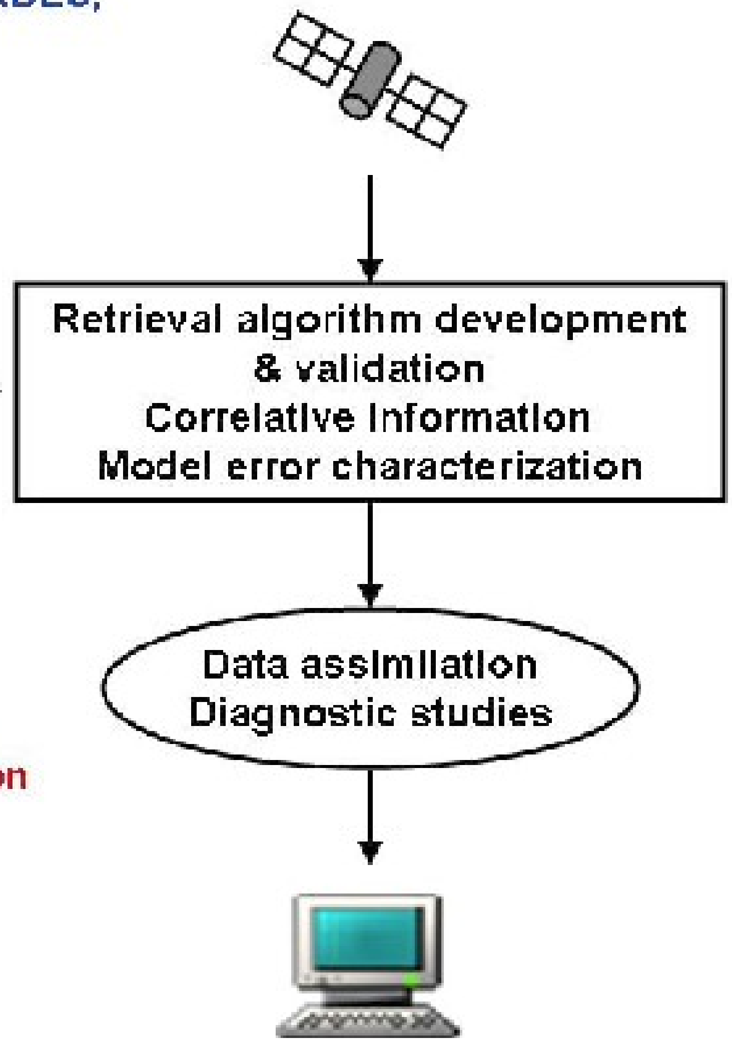
Aircraft: DC-8 and smaller platforms



- Detailed in situ chemical and aerosol measurements
- Remote sensing of ozone, aerosol, surface properties **

Models: CTMs, GCMs, ESMs

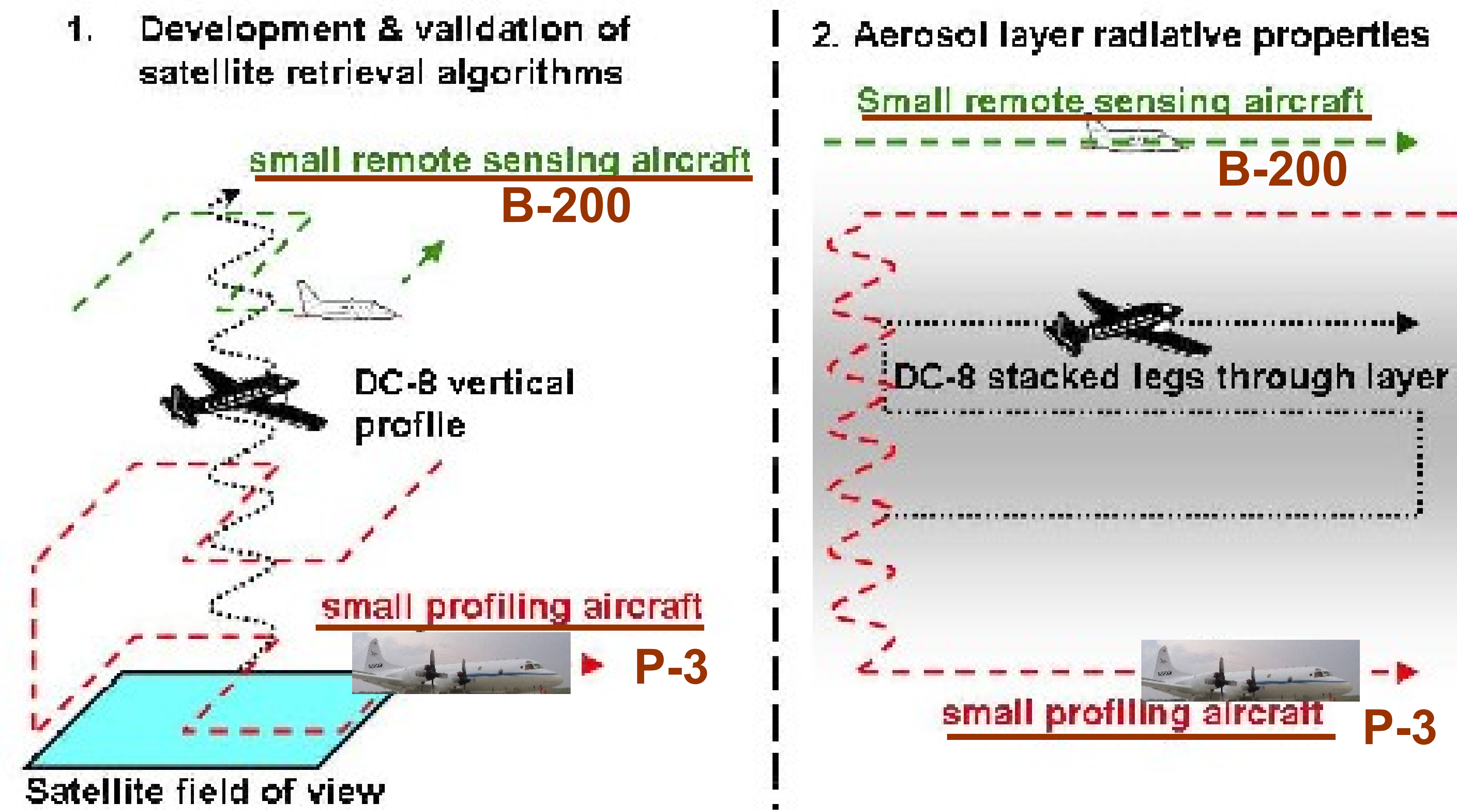
- Source-receptor relationships for Arctic pollution
- Effects of boreal forest fires
- Aerosol radiative forcing **
- Arctic chemistry



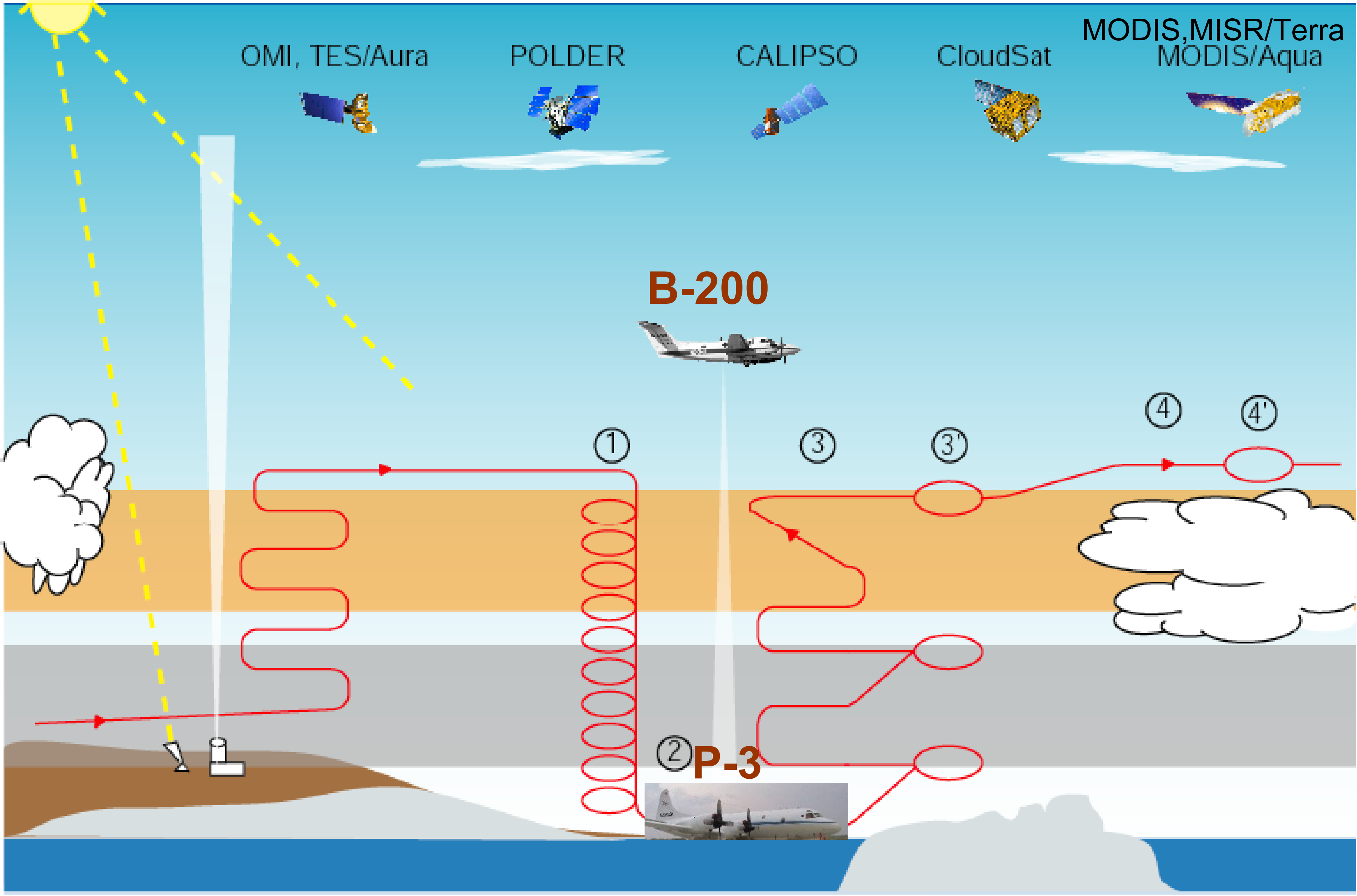
*Source: ARCTAS White Paper

**+ clouds & radiation

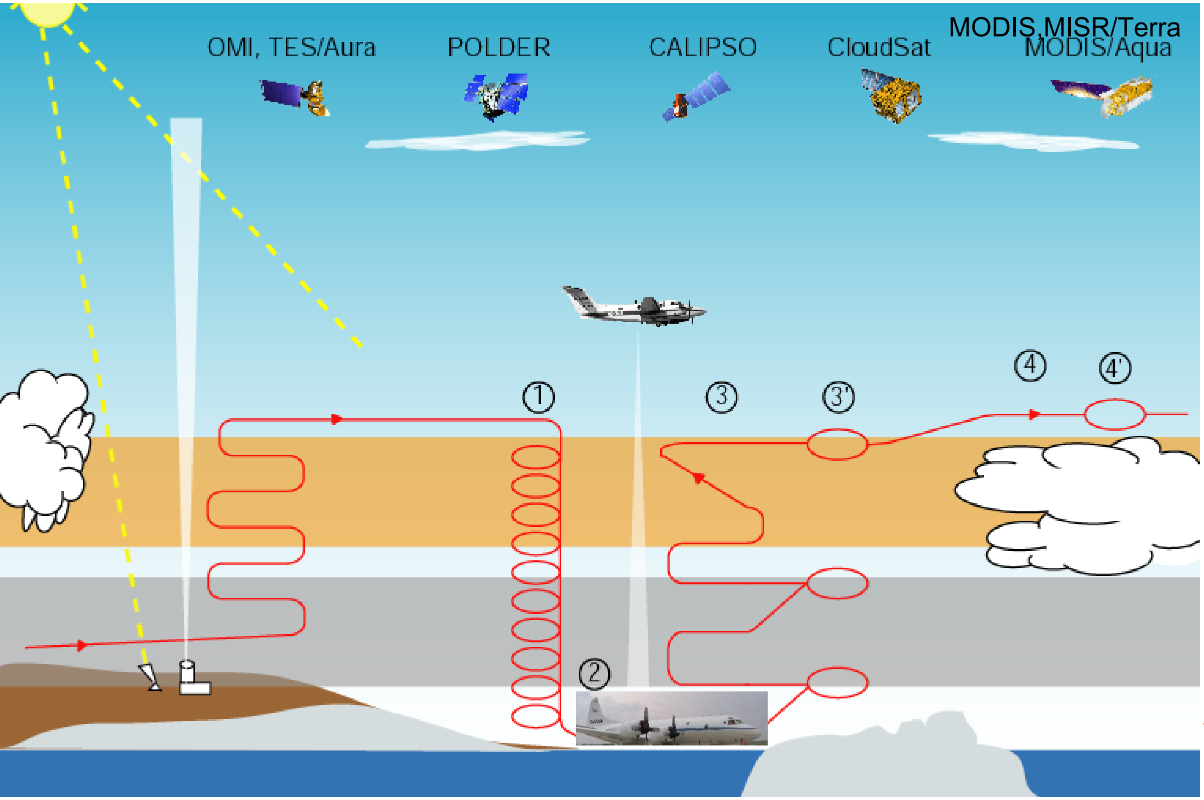
Coordinated flights of DC-8 and smaller aircraft for investigating aerosol radiative effects



Expected P-3 Flight Patterns for Aerosol-Cloud-Radiation Goals in ARCTAS



The scientific goals of the P-3 require flights containing the basic elements or patterns shown below.



(1) Survey Vertical Profile.
(2) Minimum-Altitude Transect.
(3) Parking Garage (Stepped Profile with legs of 3-15* minutes).
(3') Parking Garage with CAR Maneuvers.
(4) Above-Cloud Transect.
(4') Above-Cloud CAR Maneuver.
*15 min for in situ samples

- Many P-3 scientific instruments measure sunlight, which is strongly influenced by clouds.
- Hence, P-3 flight patterns are cloud-sensitive: many seek to avoid clouds, while others seek to fly above certain types of clouds.
- Because clouds can change quickly and are difficult to predict, P-3 flight plans usually require flexibility to change in response to clouds.

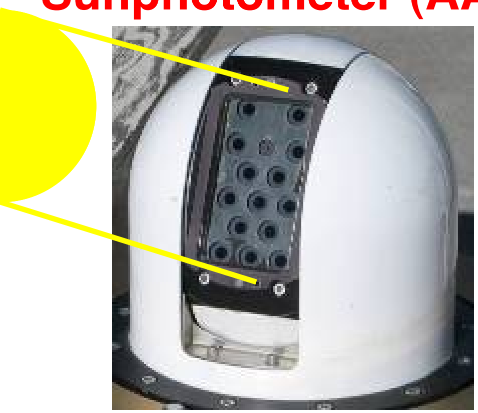
P-3 Flights—Operational Overview

- 9 Science Flights (72 hrs) from Fairbanks and/or Thule (1-21 April 2008)
- 3 Science Flights (25 hrs) from Palmdale, CA
  + 8 Science Flights (64 hrs) from Cold Lake, Alberta
  (20 June-14 Jul 2008)
- Typical flight duration: 3-10 hours
- All or most science flight hours during daylight. Nominal takeoff between 6 AM and 4 PM local. Fly 7 days/week.
- "Parking Garage" pattern is a stepped profile with ramped legs linking horizontal legs, each 3-15* minutes long.
- Ascent & descent rates <1000 ft/min in spirals & parking garages
- Timing is critical on flights coordinated with satellite overpasses and with other aircraft (NASA B-200 & DC-8, NOAA P-3).

*15 minutes for in situ sample

P-3 in ARCTAS: Payload

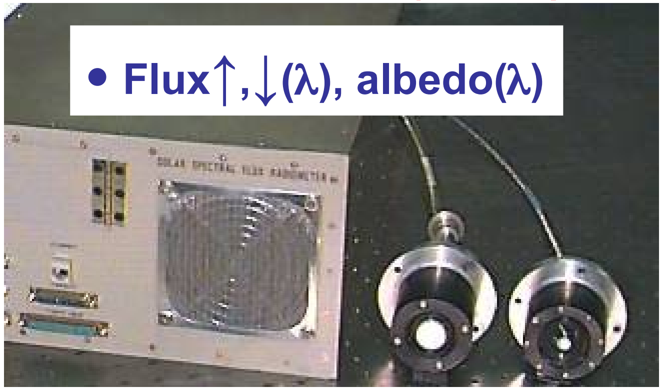
Ames Airborne Tracking Sunphotometer (AATS)



- AOD
- Ext
- H_2O vapor

Solar Spectral Flux Radiometer (SSFR)

- Flux↑,↓(λ), albedo(λ)



Broad-Band Radiometers (BBR)

LW SW

- Flux↑,↓, albedo

HiGEAR Aerosols

- OPC & DMA dry size dist, volatility
- Tandem Volatility DMA
- Neph scat + PSAP abs
- Humidified Neph f(RH)
- Ultrafine & CN
- Time of Flight Mass Spec size resolved chemistry
- SP2 black carbon mass

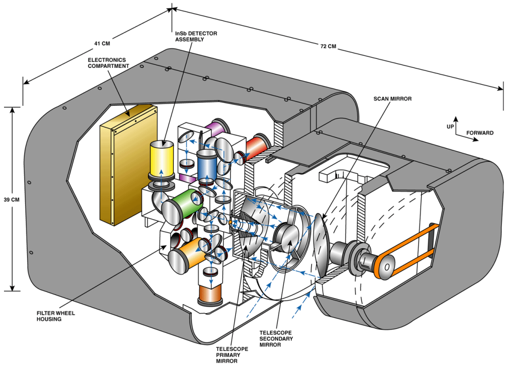
AERO3X

- Cavity Ringdown ext (2λ)
- Reciprocal Neph sca (2λ, RH

- Nenes CCN
- PVM cloud drop r_{eff}
- TECO O_3

Cloud Absorption Radiometer (CAR)

- Radiance, BRDF



Navigation

Meteorology: P, T, RH, …

REVEAL

P-3 Typical Flight Plans

This is a collection of preliminary flight plans for P-3 operations out of Fairbanks, Thule, Cold Lake, and/or Palmdale during the Spring and Summer 2008 ARCTAS campaign.
Note:

- **These drafts are intended to initiate negotiations with air traffic controllers on final flight plans that will accomplish as many of our scientific objectives as possible within the constraints of their air-traffic control system.**
- **These plans may not include all flight scenarios; parts of them may be combined but in general they would be shortened rather than lengthened for actual operations.**

Strawperson Flights for P-3 in ARCTAS

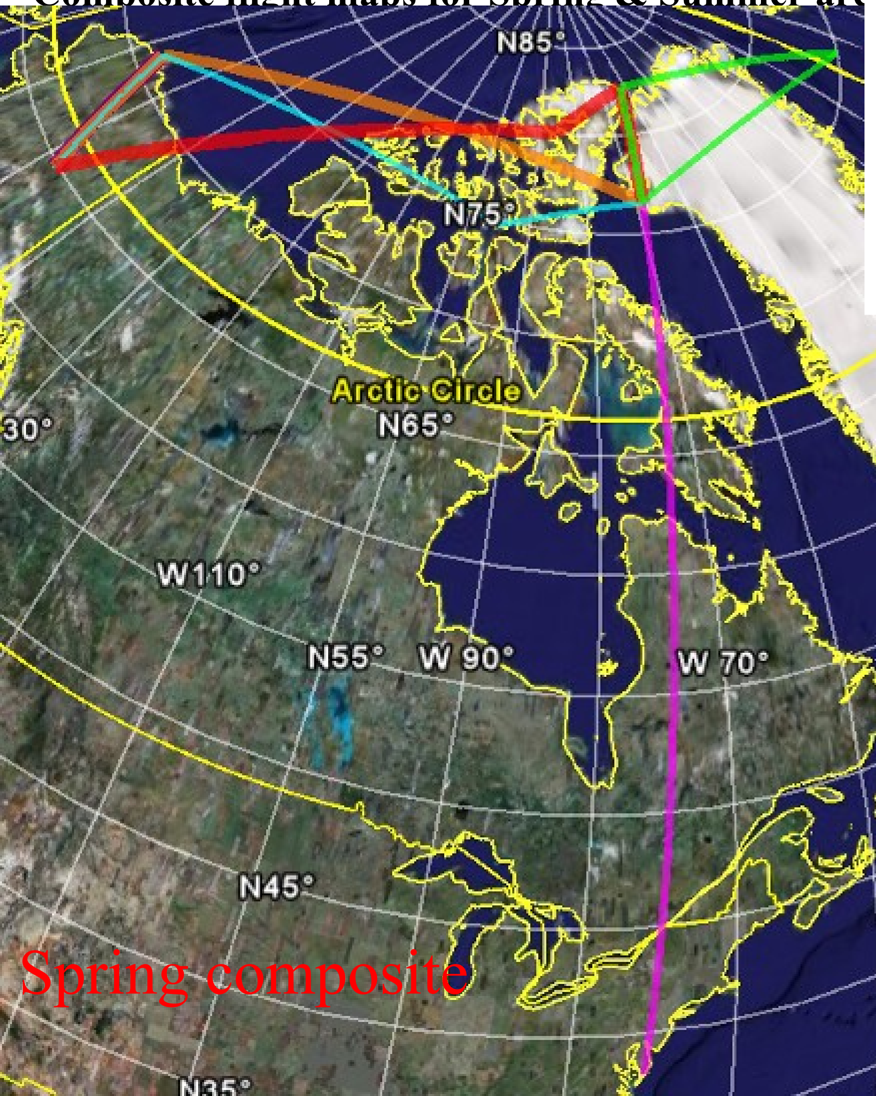
-These flight tracks are primarily intended to show areas of interest and the range of expected flight coverage.

Actual flight plans and objectives for any particular day will be dictated by conditions.

-The P-3 will span an altitude range of 200-23,000? ft.

-Ascent/descent rates will normally be 1000-1500 fpm.

-Composite flight maps for Spring & Summer are

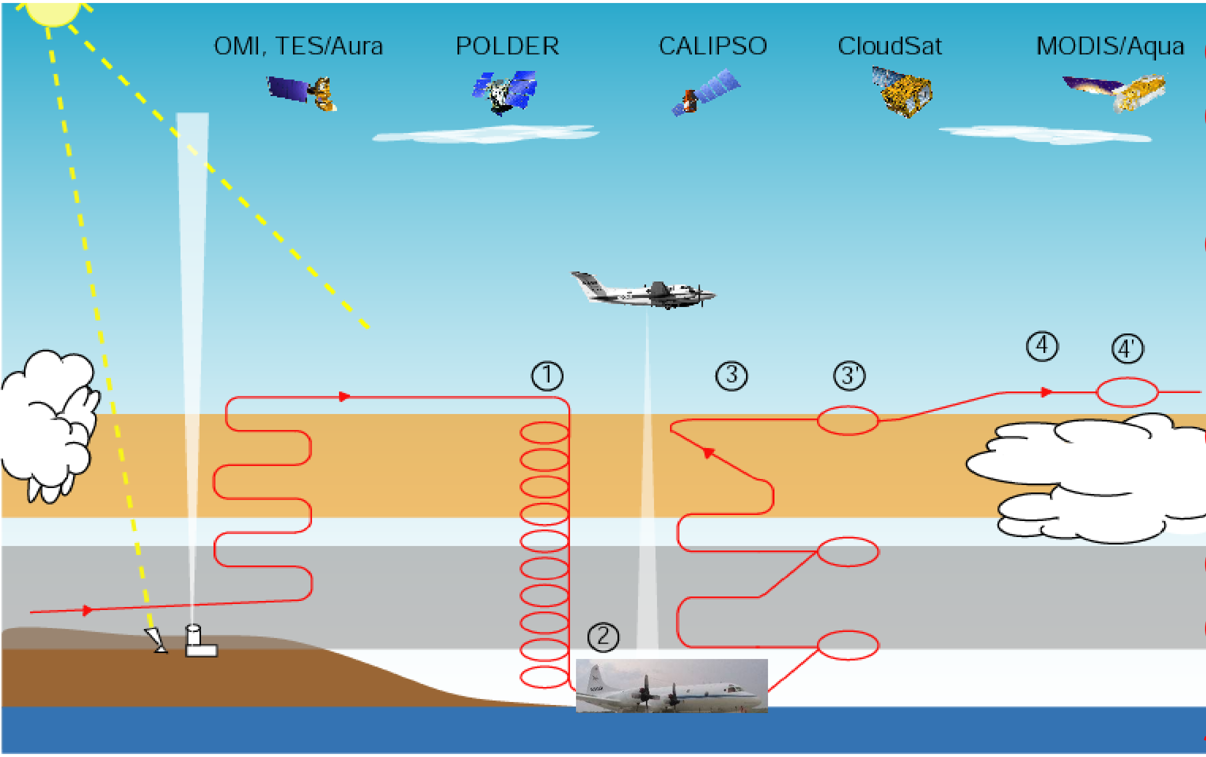


-Only ground tracks are shown, although extensive vertical profiling will be conducted along these tracks. Types of vertical profiles are shown in the next slide.

-Ground tracks represent the approximate distance covered during a flight of 9 hrs.

-Intercomparison with other research aircraft and satellite under-flights will be executed as conditions allow.

The scientific goals of the P-3 require flights containing the basic elements or patterns shown below.



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P-3 Flight 1:

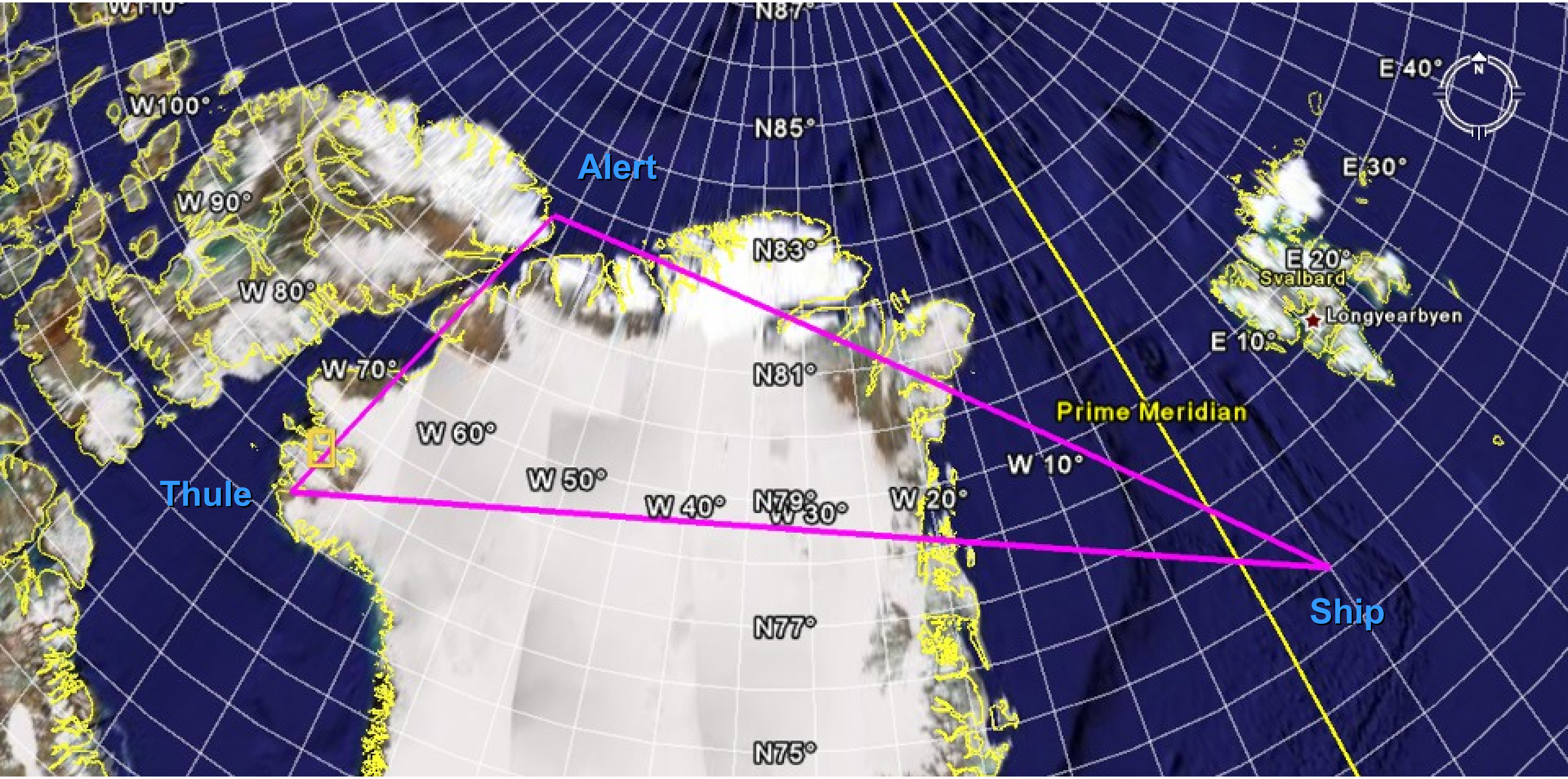
Transit, Wallops-Thule

Profile at Thule.
Possible coordination with DC-8 near Thule

P-3 Flight 2:

Thule-Alert-Ship.

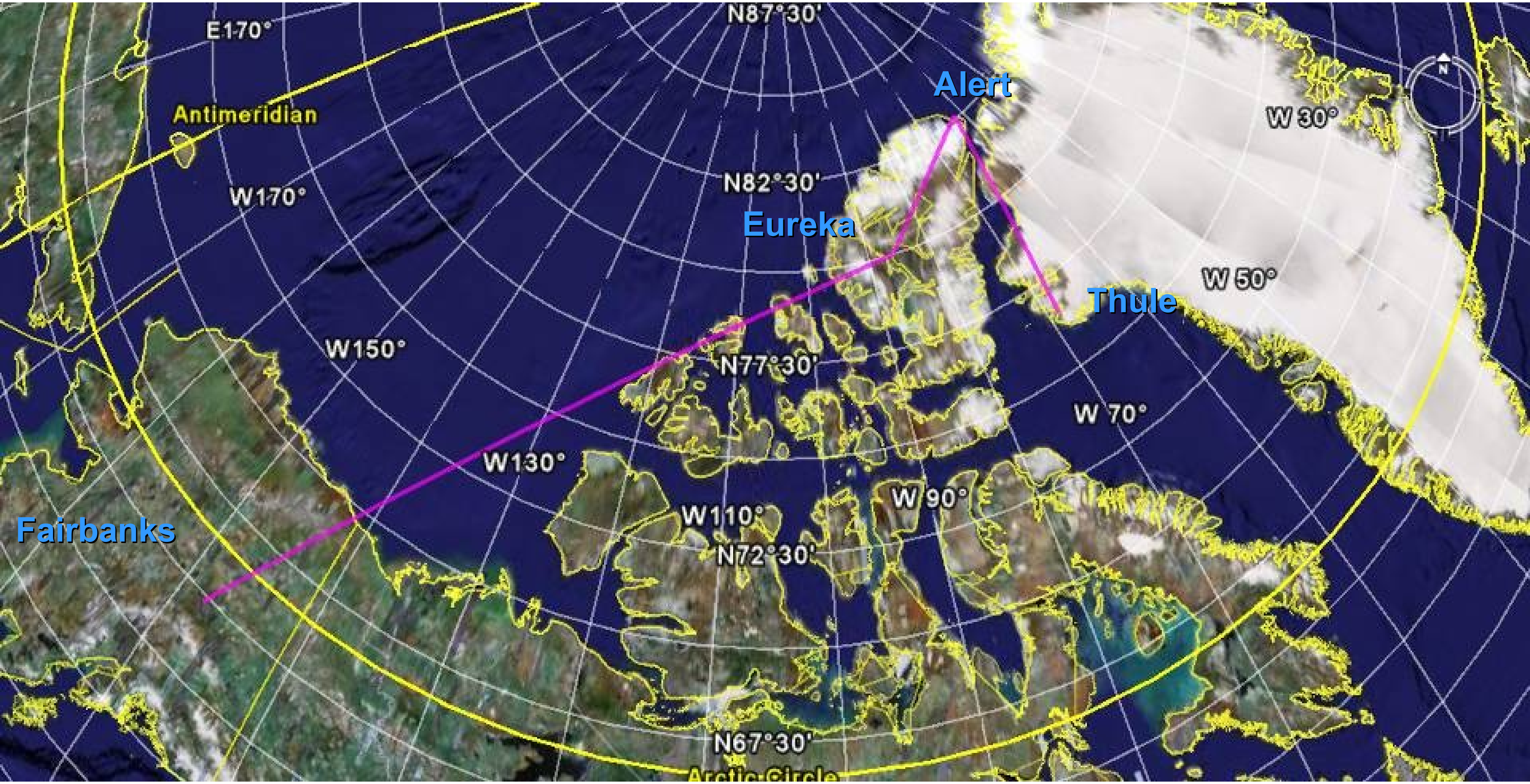
Underfly A-Train near Alert or ship. Possible coordination with DC-8 near Alert and/or ship.



P-3 Flight 3:

Thule-Alert-Eureka-Fairbanks.

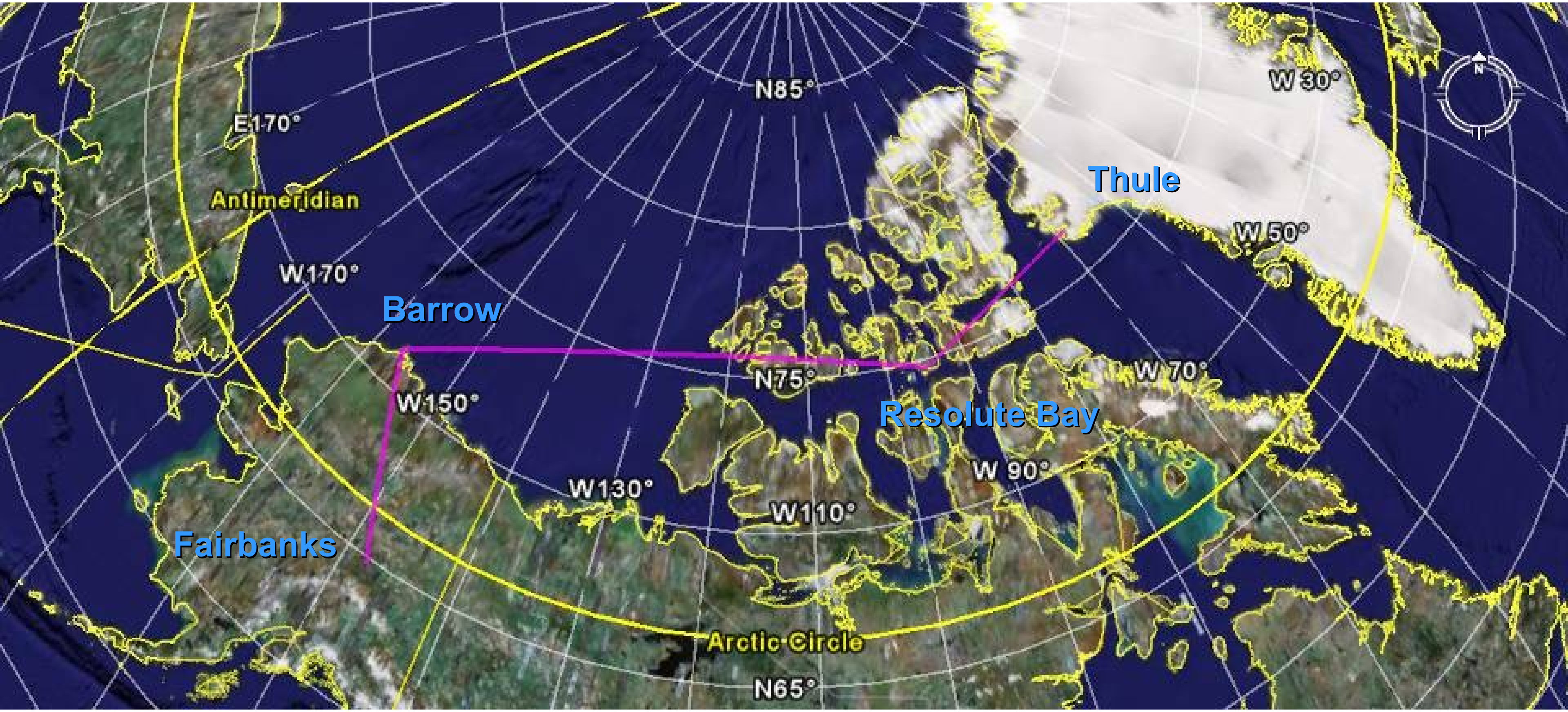
Underfly A-Train and/or Terra near Alert, Eureka, or Fairbanks. Possible coordination with DC-8 near Alert or Eureka.
Possible coordination with DC-8 and/or B-200 near Fairbanks and/or Barrow.



P-3 Flight 3B:

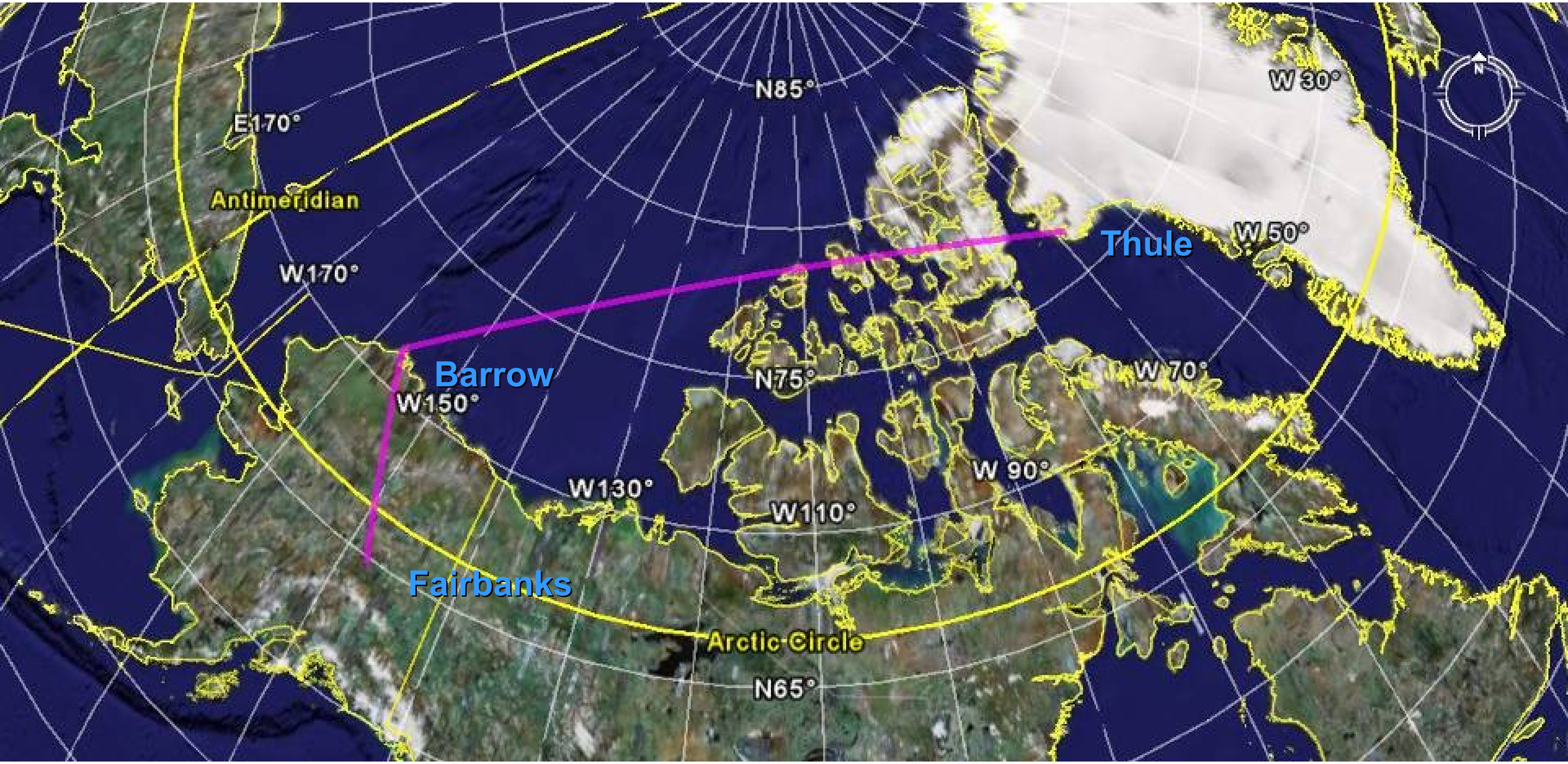
Thule-Resolute Bay-Barrow-Fairbanks.

Underfly A-Train and/or Terra near Resolute Bay, Barrow or Fairbanks.
Possible coordination with DC-8 and/or B-200 near Barrow or Fairbanks.



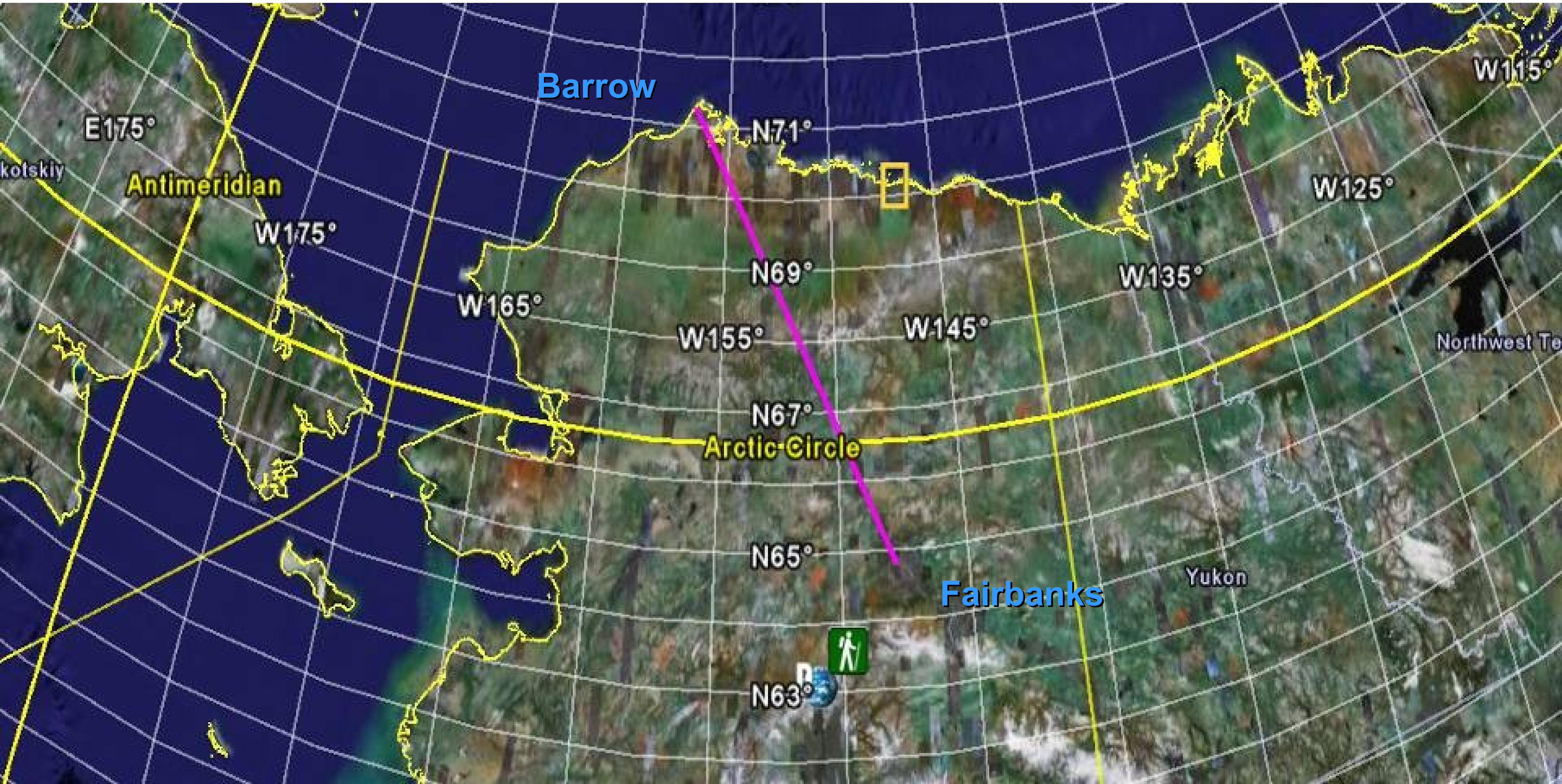
P-3 Flight 4:
Fairbanks-Barrow-Thule.

Underfly A-Train and/or Terra near Barrow or Thule.
Possible coordination with DC-8 near Fairbanks, Barrow or Thule, and/or with B-200 near Barrow or Fairbanks.



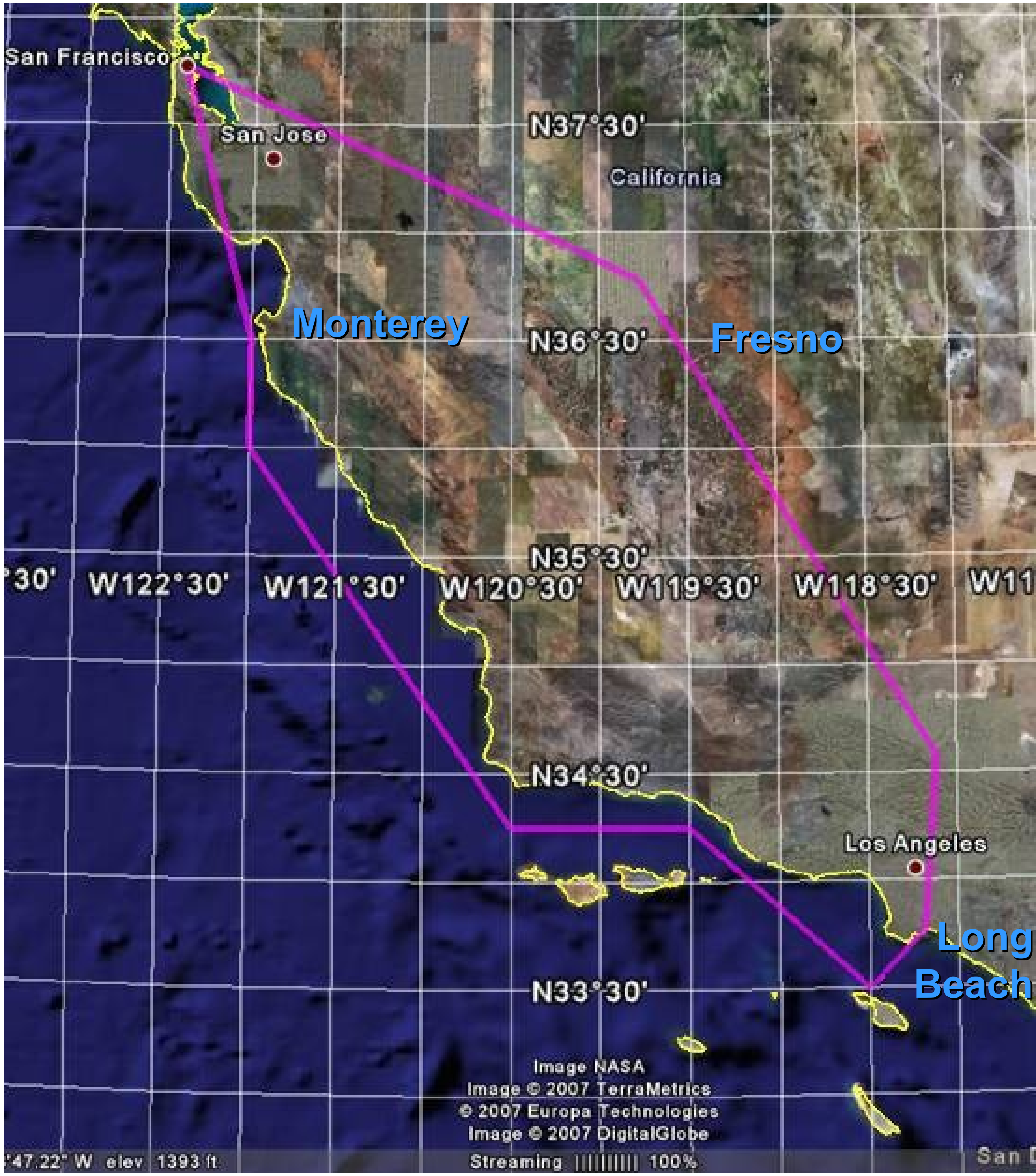
P-3 Flight 5:
Fairbanks-Barrow-Fairbanks.

Underfly A-Train and/or Terra near Barrow. Gradient legs and/or parking garage near Barrow Possible coordination with DC-8 and/or B-200 near Fairbanks or Barrow.



P-3 Flight 6: Palmdale-Fresno-San Francisco-Monterey-Long Beach-Palmdale.

Parking garages at Fresno AERONET site. Underfly A-Train and/or Terra near San Francisco and/or Monterey (possible Marine stratus-aerosol study).
Sample/study Long Beach harbor ship & marine emissions
Possible coordination with DC-8.

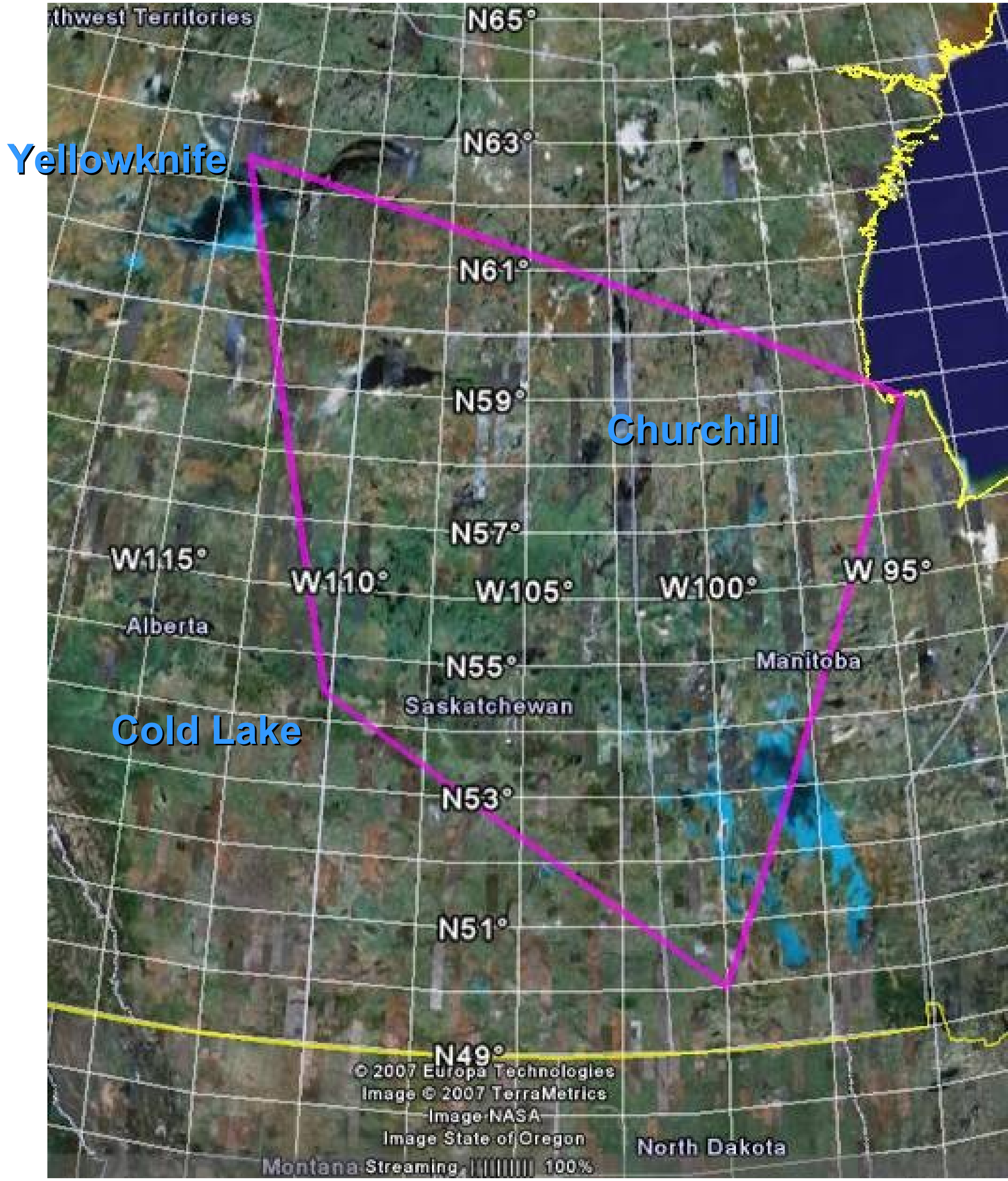


P-3 Flight 7:
Palmdale-Fresno-San Francisco-Cold Lake.

Parking garages at Fresno AERONET site. Underfly A-Train and/or Terra near San Francisco (possible Marine stratus-aerosol study).
Sample/study any smoke near route from San Francisco to Cold Lake
Possible coordination with DC-8.

P-3 Flight 8:
Cold Lake-Yellowknife-Churchill-Cold Lake.

Coordination with B-200 and/or DC-8 under A-Train or Terra in smoke near Yellowknife and other points in smoke plume.



P-3 Flight 9:
Cold Lake-Southeast Limit.

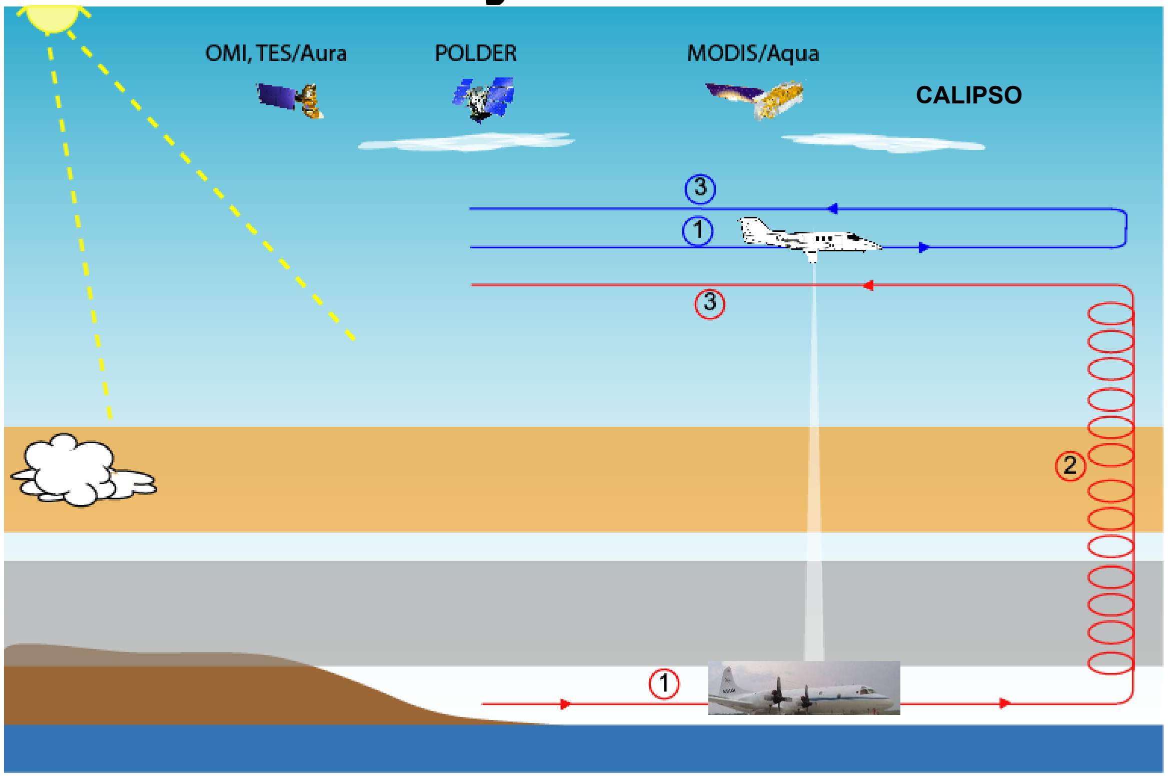
Radiation & in situ work in smoke plume as far southeast as we can go & get back to Cold Lake. Coordination with A-Train or Terra & possibly DC-8.

P-3 Flight Modules

Following are some flight modules adapted by me from those developed by Jens Redemann & other J-31 PIs for INTEX-B.
Note:

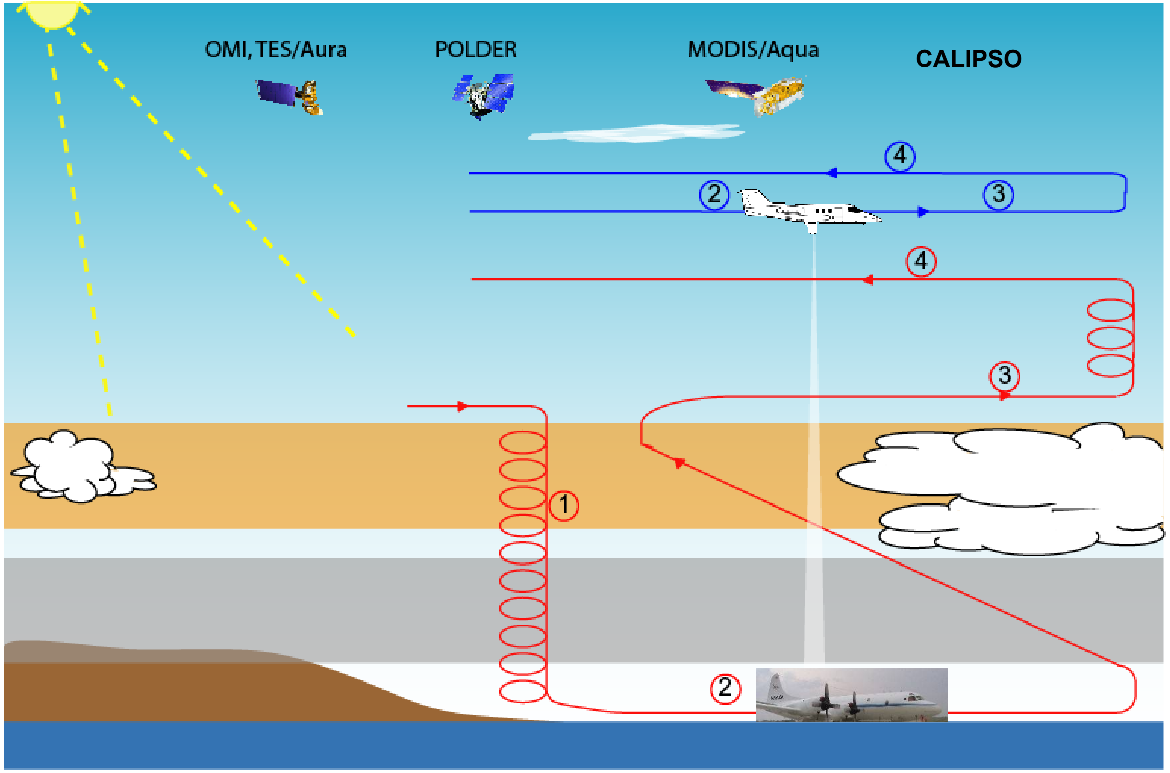
- **I’m not sure we’ll need or want these for the initial negotiations with air traffic controllers.**
- **However, it’s a good idea to start thinking about such modules now, to help us communicate with each other regarding our flight desires, synergistic science, etc.**
- **Having a good set of these modules should speed up our flight planning during the deployments.**

Clear sky, Module 1



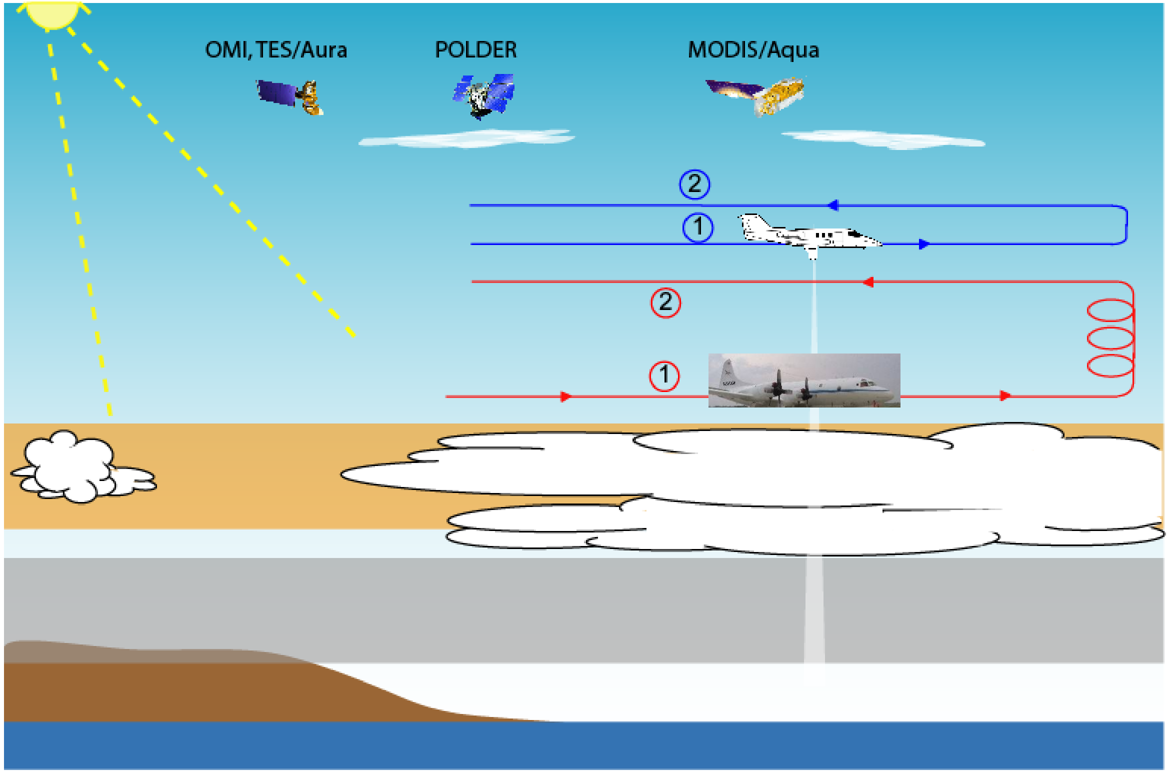
Clear Module 1	Science objectives	P-3 instruments involved	Coordination with instruments on other aircraft	Coordination with satellite-instruments
	-Find AOD+flux gradients -Compare HSRL, AATS, HiGEAR, AERO3X, CALIPSO ext. profiles	AATS, SSFR, BBR, HiGEAR, AERO3X, CAR	B-200 – HSRL+RSP	CALIPSO – CALIOP Aqua - MODIS PARASOL - POLDER Aura - OMI, TES Terra - MISR

Partly cloudy, Module 1



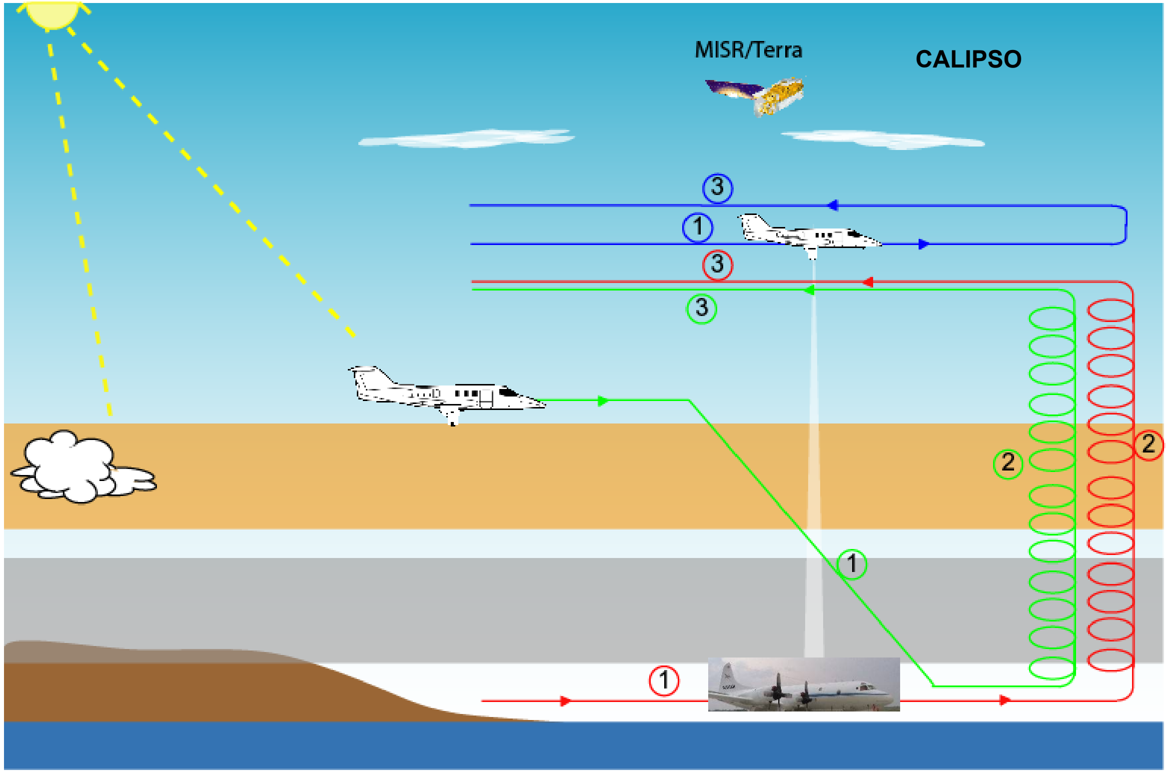
Partly cloudy Module 1	Science objectives	P-3 instruments involved	Coordination with instruments on other aircraft	Coordination with satellite-instruments
	-Study AOD in vicinity of clouds (aerosol-cloud sep.) -Aerosol indirect effect -Compare RSP+SSFR cloud retrievals	AATS, SSFR, HiGEAR, AERO3X	B-200 – HSRL+RSP	CALIPSO Aqua - MODIS PARASOL - POLDER Aura - OMI, TES

Cloudy, Module 1



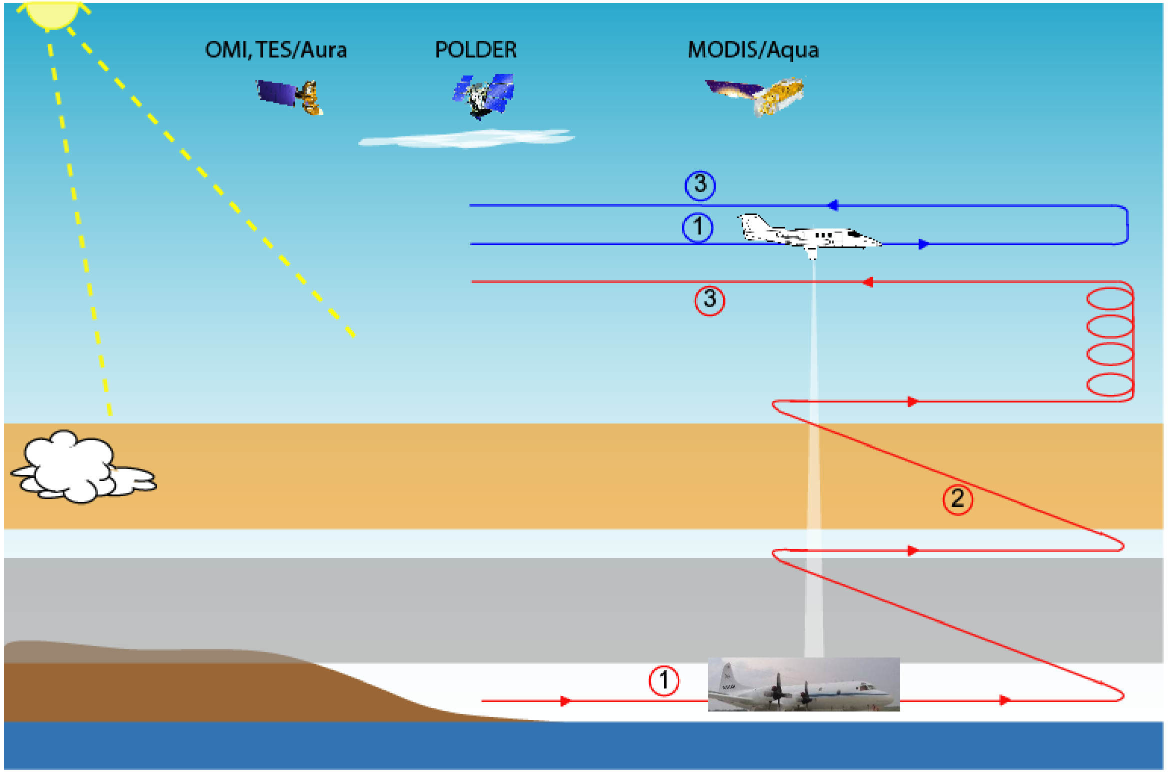
Cloudy Module 1	Science objectives	P-3 instruments involved	Coordination with instruments on other aircraft	Coordination with satellite-instruments
	-Compare RSP+SSFR cloud retrievals -Aerosol above clouds	AATS, SSFR, BBR, HiGEAR, AERO3X, CAR	B-200 – HSRL+RSP	Aqua - MODIS PARASOL - POLDER Aura - OMI, TES

Clear sky, Module 2



Clear Module 2	Science objectives	P-3 instruments involved	Coordination with instruments on other aircraft	Coordination with satellite-instruments
	-MISR local mode val. -Closure AATS+SSFR vs. DC-8 in situ -Compare HSRL+AATS+HiGEAR+AERO3X+CALIPSO ext.	AATS, SSFR, HiGEAR, AERO3X, CAR	B-200 – HSRL+RSP DC-8 – in situ + lidar	Terra – MISR Terra – MODIS CALIPSO A-Train

Clear sky, Module 3

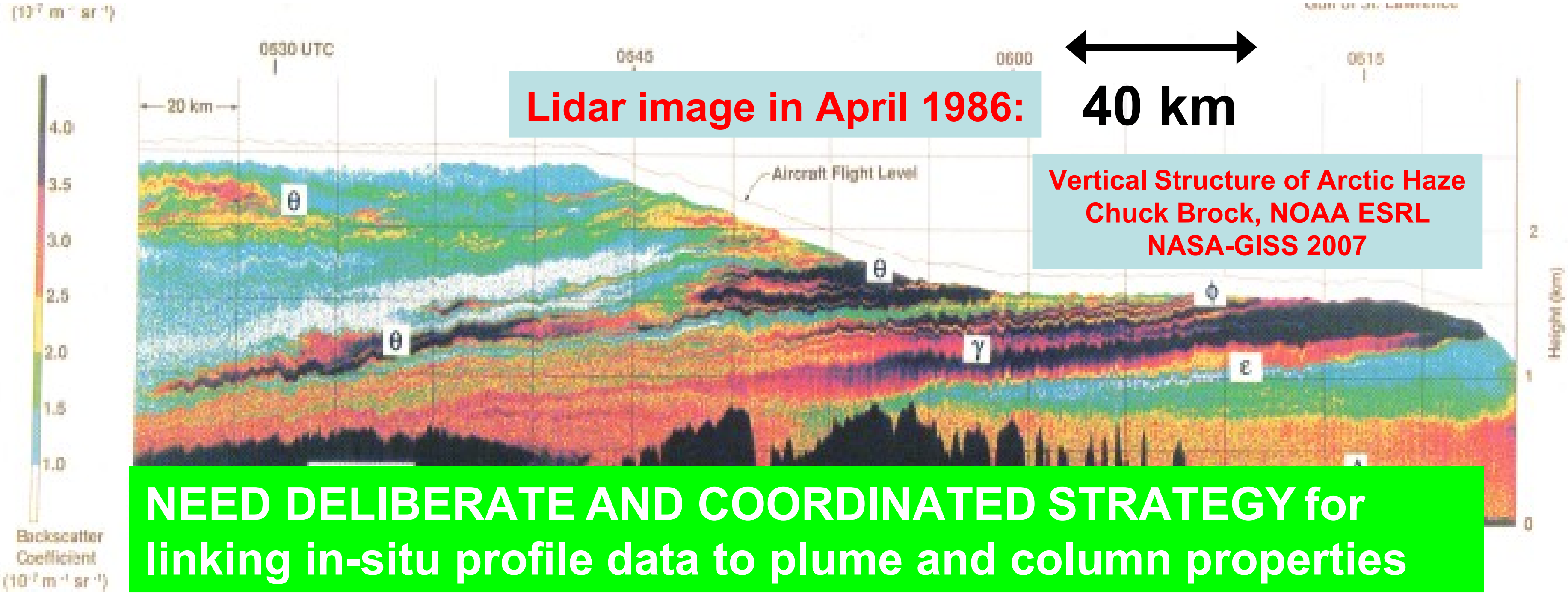


Clear Module 3	Science objectives	P-3 instruments involved	Coordination with instruments on other aircraft	Coordination with satellite-instruments
	-SSFR+AATS flux divergence for aerosol absorption compared to HiGEAR, AERO3X in situ	AATS, SSFR, BBR, HiGEAR, AERO3X, CAR	B-200 – HSRL+RSP	Aqua – MODIS (possibly in-glint) PARASOL - POLDER Aura - OMI, TES

Lidar image in April 1986:

40 km

Vertical Structure of Arctic Haze
Chuck Brock, NOAA ESRL
NASA-GISS 2007

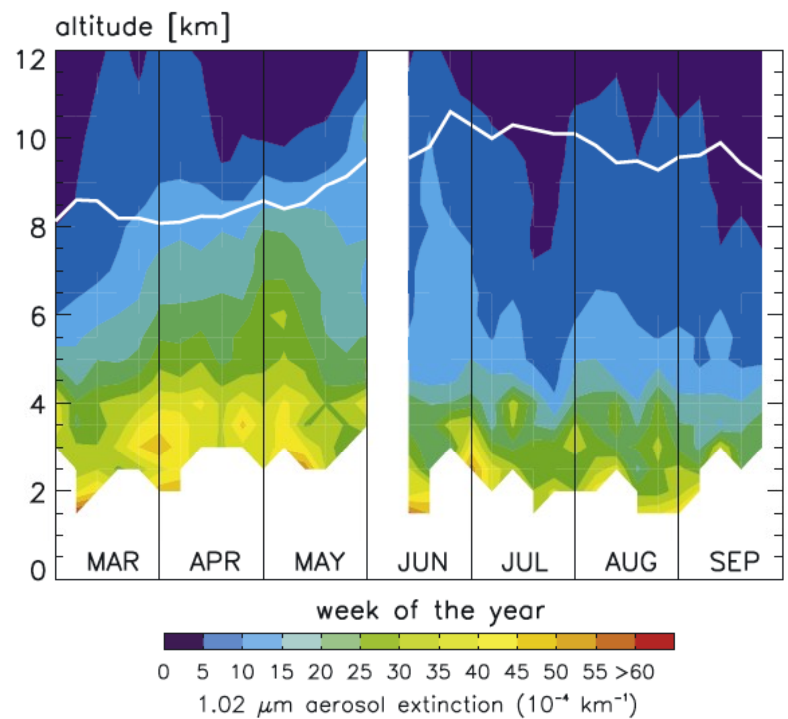


NEED DELIBERATE AND COORDINATED STRATEGY for linking in-situ profile data to plume and column properties

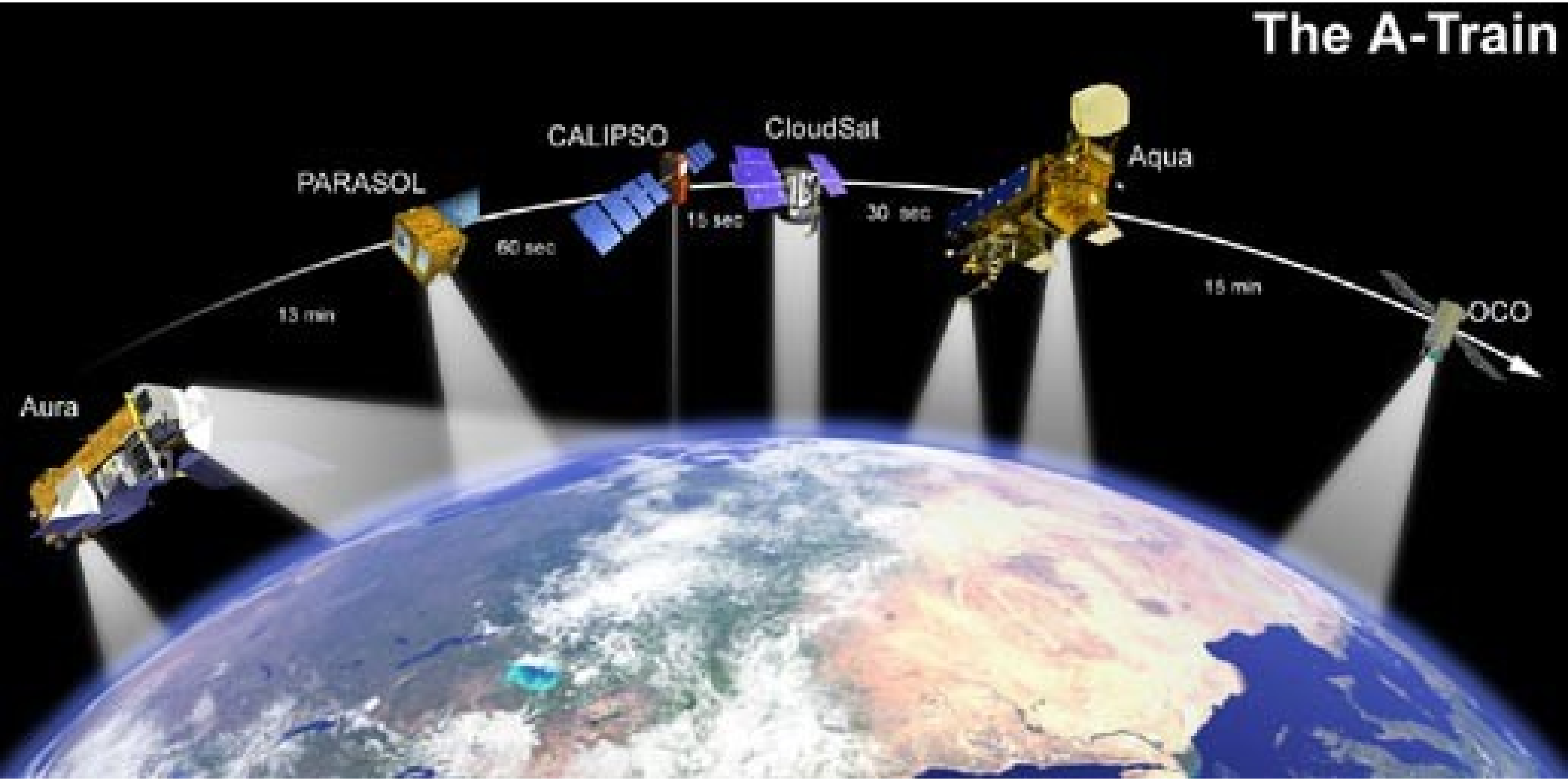
Extremely laminar transport

- **Sloping thin layers**
- **Strong gradients vertically & horizontally**
- **Frequently decoupled surface layer (relevance of surface statistics?)**
- **Highest concentrations may be aloft**
- **Diamond dust and stratus near surface**

Treffeisen et al.
SAGE II observations suggest maximum vertical extent in March-April.



The A-Train is a set of satellites that fly in sequence



Many P-3 flights will include legs or profiles under the A-Train or other satellites


Cruise begins
Woods Hole, MA, USA
17 March 2008
Initial work in Boston
Harbor and Gulf of
Maine before heading to
ICEALOT working area
Working
Area
Port Stop –Tromso,
Norway
11-15 April
Cruise ends
Iceland
28 April 2008